United States Patent [19]
Fritz

[11] 3,879,691
[45] Apr. 22, 1975

[54] PLUGGABLE FILTER UNIT

[75] Inventor: **William Baird Fritz**, Hershey, Pa.

[73] Assignee: **AMP Incorporated**, Harrisburg, Pa.

[22] Filed: Oct. 3, 1973

[21] Appl. No.: 402,938

Related U.S. Application Data

[63] Continuation of Ser. No. 266,868, June 28, 1972, abandoned, which is a continuation-in-part of Ser. No. 166,899, July 28, 1971, abandoned.

[52] **U.S. Cl.** .... **333/79**; 333/70; 339/147 P
[51] **Int. Cl.** **H01h 7/14**
[58] **Field of Search**...333/79, 70; 339/14 R, 176 MP, 339/147 P

[56] **References Cited**

UNITED STATES PATENTS

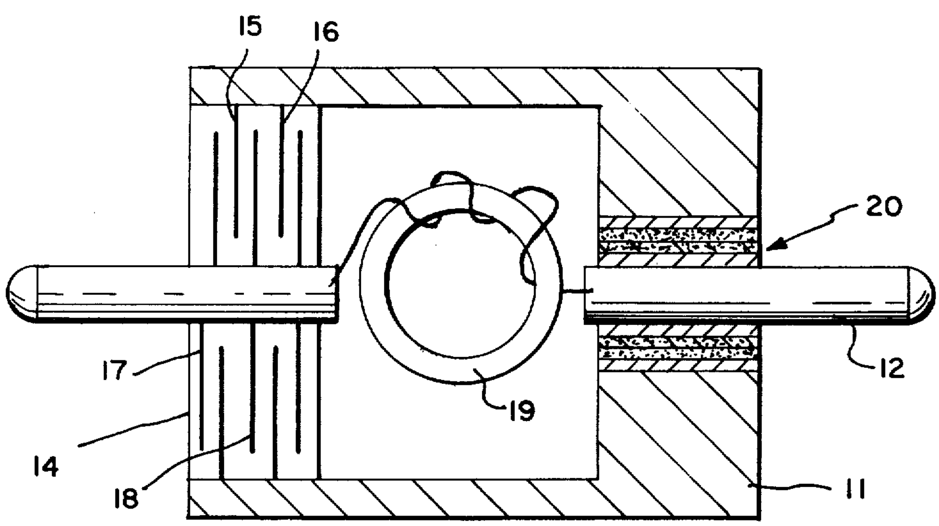
3,539,954	11/1970	Camire	333/79
3,579,155	5/1971	Tuchto et al.	333/79
3,588,758	6/1971	Hurst	333/79
3,603,902	9/1971	Denes	333/79
3,638,144	1/1972	Denes	333/79

Primary Examiner—James W. Lawrence
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney, Agent, or Firm—Gerald K. Kita

[57] **ABSTRACT**

A filter unit is disclosed as comprising a discoidal capacitor, a toroidal inductor, and a lossy ceramic filter component, all of which are disposed within a metal case. The filter network is electrically connected to connector pins at both ends of the metal case. In order to compensate for high frequency resonances in the capacitor and inductor which are lumped L-C elements, the said lossy ceramic filter is inserted in one end of the metal case. The pin at the one end extends through this lossy ceramic filter, which may be of a tubular shape, and is in electrical contact with an inner conductive surface thereof. The outer conductive surface of the lossy filter is in electrical contact with the metal case.

17 Claims, 8 Drawing Figures



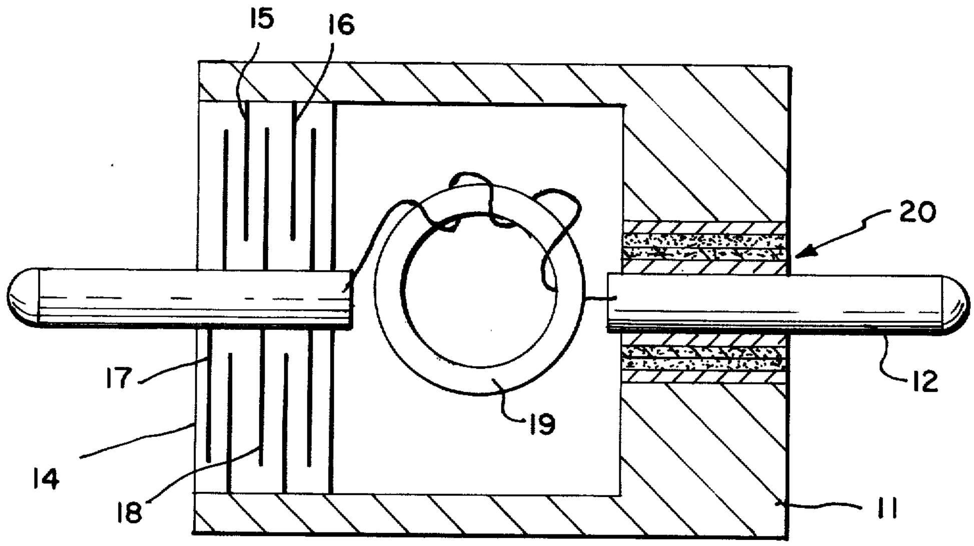


FIG. 1

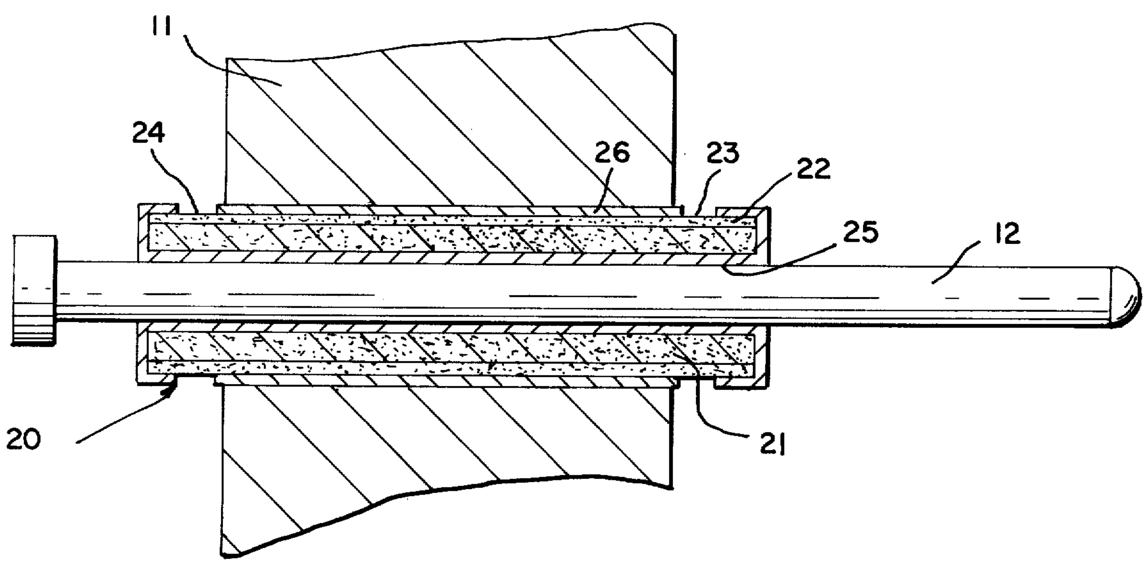
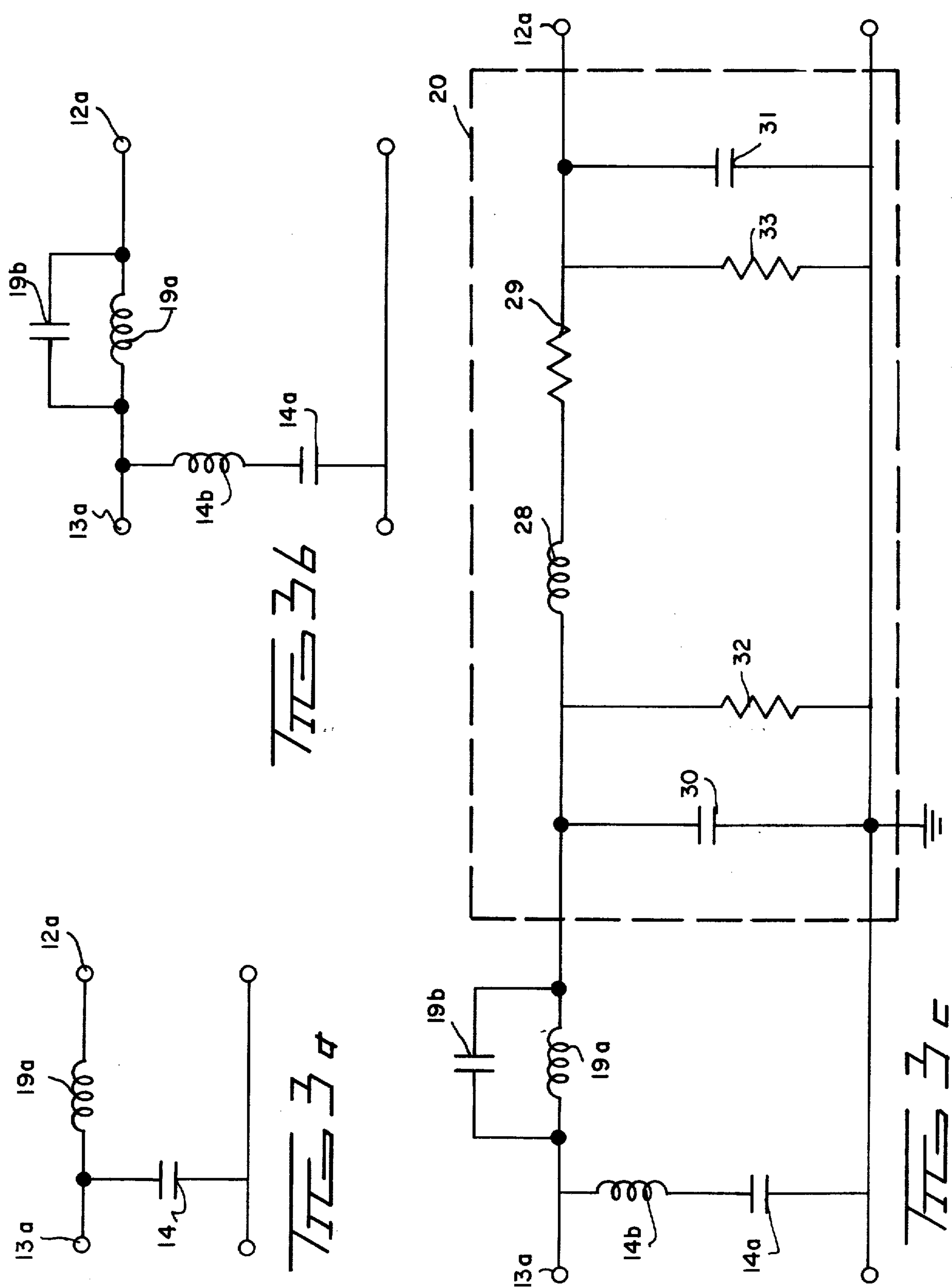


FIG. 2


12a
19b
19a
14a
14b
13a
20
31
33
29
28
32
30
19b
19a
14b
14a
13a
12a
19a
14
13a

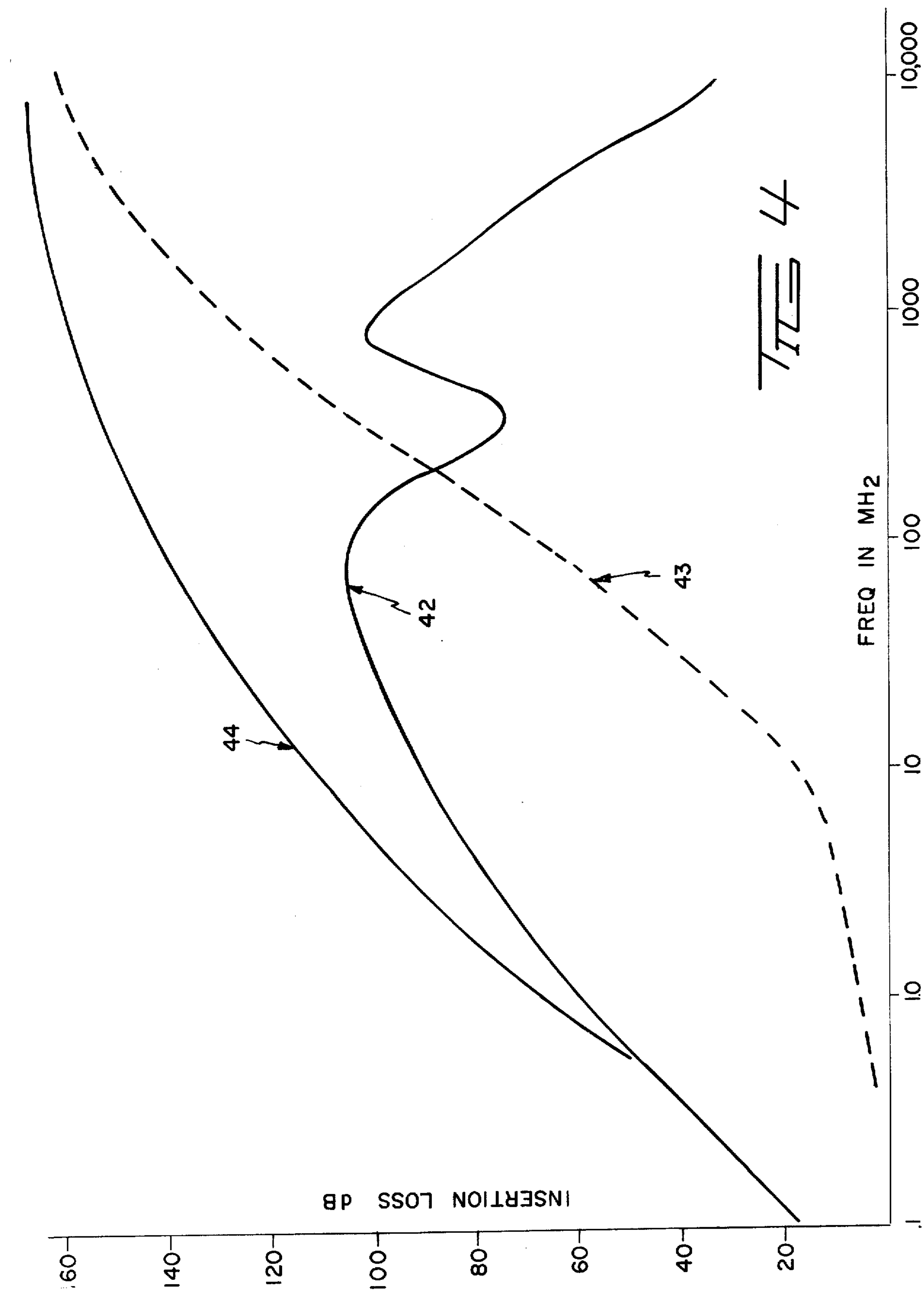

INSERTION LOSS dB
160
140
120
100
80
60
40
20
FREQ IN MHz
.1
1.0
10
100
1000
10,000
42
43
44

FIG. 4

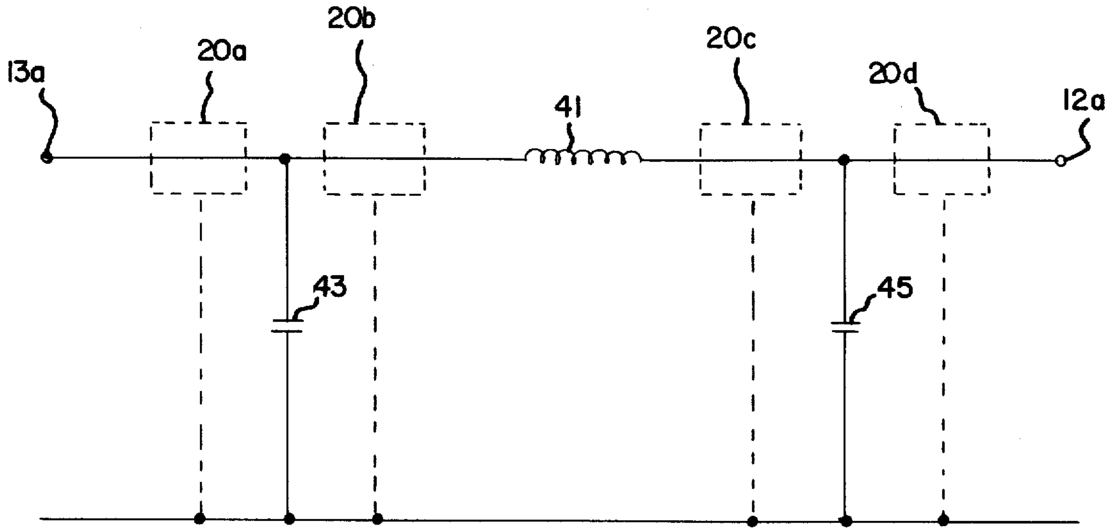


Fig. 5

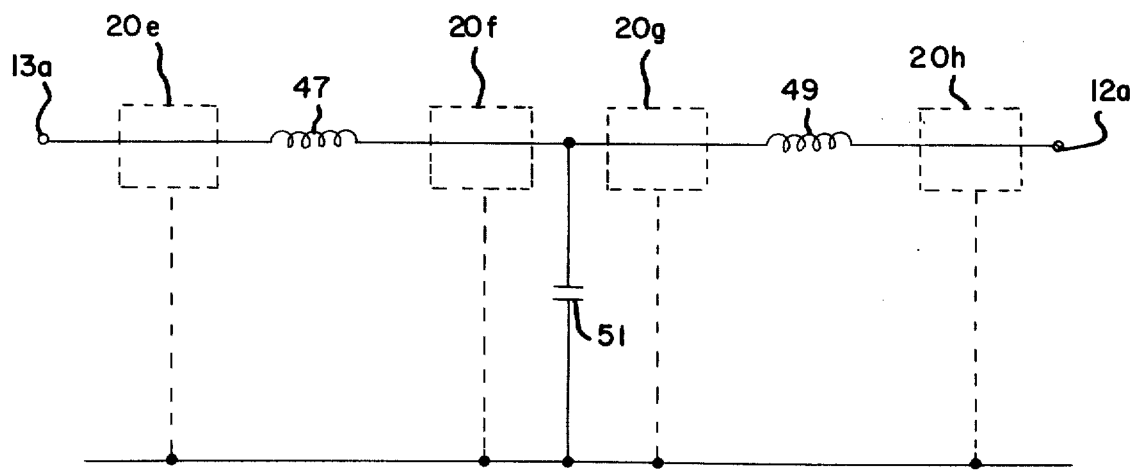


Fig. 6

PLUGGABLE FILTER UNIT

RELATED APPLICATIONS

This application is a continuation of application Ser. No. 266,868, filed June 28, 1972, which is a continuation-in part of Ser. No. 166,899, titled "Pluggable Filter Unit," filed July 28, 1971, both abandoned.

BACKGROUND OF THE INVENTION

This invention relates to filter units that must operate over a wide frequency range. More particularly, it relates to a filter unit having a lossy ceramic filter component which compensates for high frequency resonances which might otherwise be present in an L-C lumped element type of filter.

Small, easily connected, filter units are used in many applications. U.S. Pat. No. 2,759,155 - Hackenberg shows one such unit with electrical connectors at both ends. The units include an inductor and a capacitor connected to form a filter between the connectors. While such units are suitable for most applications, at higher frequencies the combination of the stray inductance of the capacitor and the stray capacitance of the inductor may produce undesired resonance.

Ceramic filters of the type shown in U.S. Pat. No. 3,275,953 - Coda, et al., have been developed and used as feed through filters or on connector pins. These filters are small and have good insertion loss characteristics at high frequencies.

SUMMARY OF THE INVENTION

In accordance with this invention, a tubular lossy ceramic filter component of the type described in the aforesaid Fritz application is inserted in one end of a pluggable filter unit. At high frequencies this ceramic filter compensates for the resonance caused by the lumped L-C components of the filter unit.

Further in accordance with this invention a particularly compact filter unit having the desired electrical characteristics is constructed by inserting the ceramic filter in one end of the filter unit case with the connector pin extending through the tubular ceramic filter. A discoidal capacitor forms the closure of the other end of the case with another connector pin extending through the discoidal capacitor. A toroidal inductor is connected between the two connector pins.

The foregoing and other objects, features and advantages of the invention will be better understood from the following more detailed description and appended claims.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal cross-section of the filter unit;

FIG. 2 illustrates the tubular ceramic filter in more detail;

FIG. 3*a* shows the desired equivalent circuit of the filter unit;

FIG. 3*b* shows the equivalent circuit with the high frequency stray inductance and capacitance of the components;

FIG. 3*c* shows the equivalent circuit of an L-type unit with the tubular ceramic filter;

FIG. 4 depicts the insertion loss characteristics of a normal filter unit, a ceramic tubular filter and a filter unit with the ceramic tubular surface in place.

FIG. 5 shows the equivalent circuit of a Pi-type unit with tubular ceramic filter; and

FIG. 6 shows the equivalent circuit of a T-type unit with tubular ceramic filter.

DESCRIPTION OF A PARTICULAR EMBODIMENT

Referring now to FIG. **1**, the filter unit includes a brass case **11** which has been silver plated and is therefore electrically conductive. A first conductive pin **12** is in one end of the case and a second conductive pin **13** forms the electrical connector at the other end of the case.

A discoidal capacitor **14** forms the closure for said other end of the case. The capacitor includes interleaved plates which are separated by dielectric material. Alternate plates **15, 16** and other corresponding plates are electrically connected to an outer conductive surface of the capacitor. This outer conductive surface is in electrical contact with the metal case **11.** The discoidal capacitor has a hole through the middle with a conductive surface around the hole. The remaining plates **17, 18** and others are connected to this inner conductive surface. The pin **13** is inserted in the hole.

One example of a discoidal capacitor is shown in the Garstang, et al., U.S. Pat. No. 3,443,251. Particularly suitable discoidal capacitors are available from U.S. Capacitor Company.

A toroidal inductor **19** is connected between the pins **12** and **13.** One inductor which is suitable for use is the Indiana General Toroid CS-101-06 having the appropriate number of turns as determined by the application involved.

In accordance with the present invention, a lossy ceramic filter component **20** is incorporated into the filter unit, the filter component **20** preferably having the construction described more fully in the aforementioned Fritz application Ser. No. 883,501. As will be seen hereinafter, the filter component **20** is a distributed impedance device with multiple ground return paths. The tubular ceramic filter **20** is inserted in a hole in case **11** with the pin **12** extending therethrough as depicted in the drawing.

In FIG. **2** the structure of the filter device **20** is shown in more detail. An extruded ferrite tube **21** is the filter substrate. A coating of barium titanate **22** deposited on the ferrite forms the dielectric layer. The multi-layer filter component **20** has an outer metallic plating thereon. The gaps at **23** and **24** in the metallic plating electrically isolate the plating into an inner conductive surface **25** and an outer conductive surface **26.** The outer conductive surface is in electrical contact with the case **11** and the inner conductive surface is in electrical contact with the pin **12.**

FIG. **3*a*** shows the desired equivalent circuit of such a filter with the points **12*a*** and **13*a*** representing the electrical equivalent of the pins **12** and **13** respectively. Capacitance **14*a*** is the capacitance of capacitor **14** and **19*a*** is the inductance of inductor **19.**

Unfortunately, at high frequencies the capacitor **14** has stray inductance and the inductor **19** has stray capacitance. As a result the actual equivalent circuit more nearly resembles that shown in FIG. **3*b*.** Inductance **14*b*** depicts the high frequency stray inductance of capacitor **14** and **19*b*** is the stray high frequency capacitance of inductor **19.** This combination produces resonance at high frequencies. However, by inserting the ceramic filter component **20** in the circuit, an equivalent circuit similar to that depicted in FIG. **3*c*** is obtained.

The equivalent circuit of FIG. 3*c* shows the effects of combining the distributed filter device **20** with the lumped components **14** and **19**, in accordance with the invention. The equivalent circuit now comprises the circuitry of FIG. 3*b* together with further elements including an inductance **28** and resistance **29** established by the complex permeability of the ferrite tube **21**. In addition, capacitances **30** and **31** and resistors **32** and **33** are shown which represent the path between the pin and the outer conductive surface **26**. The magnitudes of these capacitances and resistances are determined by the complex permitivity of the barium titanate-ferrite composite of the lossy filter **20**. FIG. 3*c* depicts lumped impedances with only two ground return paths. Actually, the impedances are distributed with continuous ground return paths along the length of the pin **12**. In actuality the filter network of the invention is equivalent to a lossy transmission line and therefore has extremely desirable filter characteristics over a wide frequency range (10 MHz to 12 GHz).

FIG. **4** shows the typical insertion loss characteristics for an L-C filter by curve **42** (with resonances), for a lossy ceramic filter component **20** alone by means of the curve **43**, and for the filter network of this invention by means of the curve **44**. Note that the resonances depicted by the curve **42**, as well as the decrease in insertion loss at high frequencies, are not present in the filter of the invention.

Referring now to FIG. **5**, there is shown a typical Pi-filter which is understood to have the same stray capacitance in parallel with inductor **41** and stray inductance in series with capacitors **43** and **45** as described with respect to FIG. 3*b*. The filter of FIG. **5** is connected across pins **12** and **13**. The filter of FIG. **5** could be constructed in the same manner as the filter of FIG. **1** with an additional capacitor identical to capacitor **14** on the opposite side of inductor **19**. The ceramic filter **20** of FIGS. **1** and **2** can be positioned in any of the four locations indicated by boxes **20** in phantom in FIG. **5**.

In the case of box **20*a***, the pin **13** and case **11** of FIG. **1** would be extended to the left with the filter **20** located to the left of capacitor **14** rather than as shown in FIG. **1**. For the case of box **20*b***, the filter would be placed on the pin **13** to the right of capacitor **14**. In the case of box **20*c***, the filter **20** would be placed on pin **12** to the left of a capacitor similar to capacitor **14** but positioned where filter **20** is shown in FIG. **1**. In the case of box **20*d***, the filter **20** would be placed on pin **12** to the right of the capacitor depicted with respect to box **20*c***. In this way, a Pi-filter is provided having good insertion loss characteristics over a wide range.

Referring now to FIG. **6**, there is shown a typical T-filter which is understood to have the same stray capacitance in parallel with inductors **47** and **49** and stray inductance in series with capacitor **51** as described with respect to FIG. 3*b*. The filter of FIG. **6** is connected across pins **12** and **13**. The filter of FIG. **6** could be constructed in the same manner as the filter of FIG. **1** with an additional inductor identical to inductor **19** on the opposite side of capacitor **14**. The ceramic filter **20** of FIGS. **1** and **2** can be positioned in any of the four locations indicated by boxes **20** in FIG. **6**.

In the case of box **20*e***, a further portion of case **11** to the left of capacitor **14** would be provided with a second inductor and a pin and filter as shown in FIG. **1** would be placed to the left of the inductor in the case **11**. In the case of box **20*f***, the construction would be the same as for box **20*e*** with the filter positioned on a pin to the left of capacitor **14**. In the case of box **20*g*** the filter would be placed on the pin to the right of the capacitor **14** and to the left of inductor **19**. In the case of box **20*h***, the filter would be positioned as shown in FIG. **1**. In this way, a T-filter is provided having good insertion loss characteristics over a wide range.

Referring again to the embodiments of FIG. **5**, the case **11** can either have a further capacitor placed therein similar to capacitor **14** but in the right hand wall of the case or the further capacitor may be formed in a separate case with a pin passing therethrough. In the event a separate case is used, the filter **20** can be placed in the pin on either side of the capacitor, it being understood that the pin passes through the filter as described in FIGS. **1** and **2** and the filter is in contact with the case. Upon forming the Pi-filter, the two cases would be placed together in electrical contact and preferably made integral with each other.

Referring again to the embodiment of FIG. **6**, the case **11** can have either a further cavity to the left of capacitor **14** to house a further inductor or a separate case can be provided which houses a second inductor. One side wall of the separate case would have a terminal therein and another side wall would have a pin with the filter **20** thereon as shown in FIGS. **1** and **2**. The filter would take the position of **20*g*** or **20*h***, depending upon whether the terminal side or the pin side of the case faces inwardly into the mating case which contains the other inductor and capacitor. The two cases would be electrically connected together and preferably made integral with each other.

While particular embodiments of the invention have been shown and described, it will be understood that various modifications are within the scope of the invention. Thus, for example, it will be readily seen that the discoidal capacitor **14** could be replaced by any other suitable capacitance means, such as cylindrical capacitors or capacitors of the wound type. Similarly, the inductor **19** need not necessarily be a toroidal inductor. Instead it could be a tubular inductor, one having a wound coil construction, or one with a potted core. The connector pins **12** and **13** could also be replaced by any equivalent desired electrical connector means or circuit termination means.

What is claimed is:

1. A pluggable filter unit comprising:

an electrically conductive case having plural outer walls,

at least one capacitor within said case and having one side electrically connected to said case,

at least one inductor within said case and electrically connected to the other side of said capacitor, said at least one capacitor and at least one inductor being connected to form one of an L-type, T-type and Pi-type filter,

a first conductive pin in one of said outer walls of said case and an electrical terminal at the other end region of said case, and,

lossy filter means in said one of said outer walls of said case, said pin extending through said lossy filter means and being in electrical contact with an inner conductive surface of said filter means, an outer conductive surface of said filter means being in electrical contract with said case, with said inductor, said capacitor and said lossy filter means being connected as a high frequency insertion loss filter network between said pin and said terminal.

2. The filter unit recited in claim 1 wherein said lossy filter means comprises a tubular ceramic filter including:

a tube of substrate,

a dielectric coating on said tube,

a metal plating on said dielectric, a portion of which forms the outer conductive surface of said filter, said filter being inserted in a hole in said one end of said case with said outer conductive surface in contact with said case, and

the said metal plating being extended throughout the inside of said tubular ceramic filter and having gaps near both extremities of said filter to electrically isolate the portion of said plating which forms said outer conductive surface from another portion of said plating which forms said inner conductive surface.

3. The filter unit recited in claim 2 wherein said tube is an extruded tube of ferrite.

4. The filter unit recited in claim 3 wherein said dielectric is a coating of barium titanate on said tube of ferrite.

5. The filter unit recited in claim 1 wherein said at least one capacitor is a discoidal capacitor having interleaved plates separated by dielectric, alternate plates being electrically connected to an outer surface of said capacitor which is in electrical contact with said case, the other plates being electrically connected to said electrical connector.

6. The filter unit recited in claim 5 wherein said electrical connector is a second conductive pin and wherein said discoidal capacitor is of the type having a hole in the middle, said second pin being inserted in said hole, said other plates being electrically connected to an inner conductive surface in said hole which is in electrical contact with said second pin.

7. The filter unit recited in claim 6 wherein said discoidal capacitor forms the closure of at least one end of the case.

8. The filter unit recited in claim 1 wherein said connector is a second conductive pin and wherein said inductor is a toroidal inductor electrically connected between said first pin and said second pin.

9. A filter unit comprising:

an electrically conductive case having a hollow interior,

capacitance means disposed within said hollow interior of said case,

inductive means disposed within said hollow interior of said case and electrically connected to said capacitance means,

electrical connector means mounted in and extending through said case and providing input and output connections for said filter unit,

lossy filter means mounted in and extending through said case with at least a portion of said electrical connector means extending through said lossy filter means and being in electrical contact with an inner conductive surface thereof, an outer conductive surface of said lossy filter means being in electrical contact with said case, and

means for connecting said capacitance means, said inductive means, and said lossy filter means together to form a high frequency insertion loss filter network.

10. The filter unit recited in claim 9 wherein said capacitance means comprises two capacitors arranged in Pi-filter configuration with said inductance means.

11. The filter unit recited in claim 9 wherein said inductance means comprises two inductors arranged in a T-filter configuration with said capacitance means.

12. A low phase broad band feed-through line filter assembly which comprises:

a. a unitary casing support of electrically conductive material,

b. low frequency filter means providing filtering of frequencies in the range of about 1 megahertz to about 20 megahertz with rapid fall off of filtering capability,

c. a tubular ceramic high frequency lossy filter surrounded by said casing and having distributed impedance in series with said low frequency filter means providing filtering of frequencies from 10 10 megahertz to about 12 gigahertz,

d. whereby said lossy filter cancels resonances from said low frequency filter means in the range of about 20 megahertz to about 12 gigahertz; and

e. a connector pin extendng through said tubular filter substantially along the axis thereof, said connector pin extending externally of said casing support;

f. substantially the entire outer surface of the tubular ceramic filter being conductively connected to the casing support.

13. A filter assembly as set forth in claim 12 wherein said connector pin is electrically insulated from said casing support.

14. A low pass broad band line filter as set forth in claim 12 wherein said filter means is a capacitor.

15. A low pass broad band line filter as set forth in claim 13 wherein said filter means is a capacitor.

16. A low pass broad band line filter as set forth in claim 12 wherein said filter means is a coil and a capacitor.

17. A low pass broad band line filter as set forth in claim 13 wherein said filter means is a coil and a capacitor.

* * * * *